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ABSTRACT

Total cross sections of $\pi^{\pm}$ and $K^{\pm}$ on protons and deuterons have been measured at 50, 100, 150 and 200 GeV/c. All of the cross sections rise with increasing momentum.

In the preceding paper[1] were described measurements of p and $\bar{p}$ total cross sections on protons and deuterons at 50, 100, 150 and 200 GeV/c. With two gas differential Cerenkov counters in the incident beam, the cross section for another incident particle was measured simultaneously; the second counter was used for pions and kaons sequentially. We describe here the pion and kaon data, and give experimental details only when they differ from the p, $\bar{p}$ case. The differences are firstly due to a small admixture of muons and electrons in the particles identified as pions by the gas Cerenkov counter, and secondly due to the effects of pion and kaon decays.

Electrons in the gas Cerenkov pion signal were identified by their characteristic signal in a 22 radiation length lead glass Cerenkov counter placed downstream of the transmission counters. At 150 and 200 GeV/c, the contamination was less than 0.1%, while at 50 GeV/c the gas Cerenkov counter could cleanly separate pions and electrons. At 100 GeV/c, the contamination depended on the gas Cerenkov pressure setting; data taken for 100 GeV/c π^- had a contamination less than 0.1%, while for 100 GeV/c π^+ it was 0.1%. The correction to the cross section was determined using a special electron run and checked with runs where the cross section was measured with varying electron contaminations.

Muons, which were $\sim$ 1% of the pions in the beam, were identified by their ability to pass through 5 meters of steel placed downstream of the transmission counters. Measurements made with different amounts of steel showed that 5 meters of steel caused a negligible loss of muons, but adequate attenuation of pions. A $\sim$ 0.5% correction to the pion cross sections was necessary for particles produced by pions interacting in the steel, escaping from its sides, but still giving a count in the muon scintillation counter; the correction was determined using incident protons.

From these data, the number of muons in the pion beam at the hydrogen target could be determined. In the case of kaons, this measurement was used to determine the number of kaons at the hydrogen target which was less than the number indicated by the gas Cerenkov counter due to decays between the Cerenkov counter and target.

The extrapolation of the partial cross sections to t = 0 was carried out using the expression:

$$\sigma_i = \sigma_T \exp\,(At_i + Bt_i^{\,2} + Ct_i^{\,3})$$

where σ_i is the partial cross section measured by the i^{th} transmission counter combination subtending a maximum t_i, and σ_T is the total cross section. The $Ct_i^{\,3}$ term was needed only for $\pi^{\pm}$ and K^+ on deuterons; in the other cases no improvement in the fit was obtained when it was added and so C was set equal to zero.

Momentum dependent uncertainties for a particular incident particle in the pion data are ±0.25%, mainly due to uncertainties in the muon and electron contamination. For kaons, they are dominantly given by the statistical errors. Overall momentum independent scale uncertainties are ±0.5% for cross sections on protons and ±0.6% for cross sections on deuterons.

Results of this experiment are shown in Figures 1 and 2, together with previous data[2-7], and are listed in Table I. The cross sections for $\pi^{\pm}$ and $K^{\pm}$ all show a rise with increasing momentum (the π^{-} p rise is about 3.5 standard deviations).

The cross sections for $\pi^{\pm}d$ shown in Fig. 1b are equal within our errors as required by charge symmetry. Averaging the four momenta, we obtain $\sigma(\pi^{-}d)/\sigma(\pi^{+}d) = 1.0014 \pm 0.0019$. Using $\pi^{\pm}$ d and $\pi^{\pm}$ p cross sections, the parameter $\langle r^{-2} \rangle$ in the Glauber-Wilkin,[8,9] shielding expression can be derived, and is shown in Fig. 1C and in Table I. This parameter appears to be constant over our momentum range, averaging 0.039 mb^{-1}. We have used this value in deriving the kaon cross sections on neutrons shown in Fig. 2C and Table I; a momentum independent uncertainty of ±0.7% is assigned to allow for uncertainties in this procedure. The momentum dependence of the neutron cross sections is very similar to those on protons.

Antiparticle-particle cross section differences are given in Table I and shown in Fig. 3; note that a number of uncertainties common to both cross sections cancel in these differences. In all cases the differences can be fit by the form $As^{\alpha-1}$; using our data only, we obtain $\alpha = 0.60 \pm 0.10$, 0.45 ± 0.07 and 0.39 ± 0.08 for $\sigma_{\pi^-p} - \sigma_{\pi^+p}$, $\sigma_{K^-p} - \sigma_{K^+p}$ and $\sigma_{K^-d} - \sigma_{K^+d}$ respectively.

There are a number of relations between total cross sections predicted by quark and Regge Pole models; Denisov et al.[6]

tested them with data up to 65 GeV/c and found general agreement. Our data up to 200 GeV/c also shows general agreement with these relations.

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TABLE I

RESULTS OF THIS EXPERIMENT. CROSS SECTIONS IN MILLIBARNS

	MOMENTUM (GeV/c)				
	50	100	150	200	Momentum independent Scale uncertainty
$\sigma_{\pi^- p}$	24.01±0.06	23.96±0.07	24.07±0.06	24.28±0.06	±0.5%
$\sigma_{\pi^- d}$	45.51±0.12	45.50±0.12	45.76±0.12	46.21±0.12	±0.6%
$\sigma_{\pi^+ p}$	23.07±0.06	23.29±0.06	23.46±0.06	23.73±0.09	±0.5%
$\sigma_{\pi^+ d}$	45.33±0.12	45.39±0.12	45.74±0.12	46.29±0.16	±0.6%
$\sigma_{K^- p}$	20.25±0.11	20.41±0.08	20.57±0.09	20.84±0.09	±0.5%
$\sigma_{K^- d}$	38.76±0.15	39.01±0.12	39.30±0.13	39.83±0.13	±0.6%
$\sigma_{K^- n}$	19.75±0.18	19.85±0.13	20.01±0.14	20.30±0.15	±0.7%
$\sigma_{K^+ p}$	18.03±0.09	18.85±0.08	19.33±0.08	19.84±0.10	±0.5%
$\sigma_{K^+ d}$	35.55±0.16	36.72±0.14	37.71±0.14	38.44±0.17	±0.6%
$\sigma_{K^+ n}$	18.56±0.18	18.99±0.15	19.55±0.15	19.82±0.19	±0.7%
$\sigma_{\pi^- p} - \sigma_{\pi^+ p}$	0.94±0.07	0.67±0.07	0.61±0.07	0.55±0.09	
$\sigma_{K^- p} - \sigma_{K^+ p}$	2.23±0.13	1.57±0.10	1.24±0.10	1.00±0.13	
$\sigma_{K^- d} - \sigma_{K^+ d}$	3.21±0.20	2.28±0.16	1.60±0.17	1.39±0.19	
$\sigma_{K^- n} - \sigma_{K^+ n}$	1.18±0.25	0.86±0.19	0.46±0.21	0.48±0.24	
$\langle r^{-2} \rangle$ (mb^{-1})	0.0380±0.0022	0.0405±0.0022	0.0396±0.0022	0.0383±0.0022	

FIGURE CAPTIONS

Figure 1: Results of this experiment, together with previous data.

a) Total cross sections for $\pi^{\pm}$ on protons;

b) Total cross sections for $\pi^{\pm}$ on deuterons;

c) Values of the parameter $\langle r^{-2} \rangle$.

Momentum dependent errors only are shown. Previous data are from References 2-7, 10.

Figure 2: Results of this experiment, together with previous data for total cross sections of

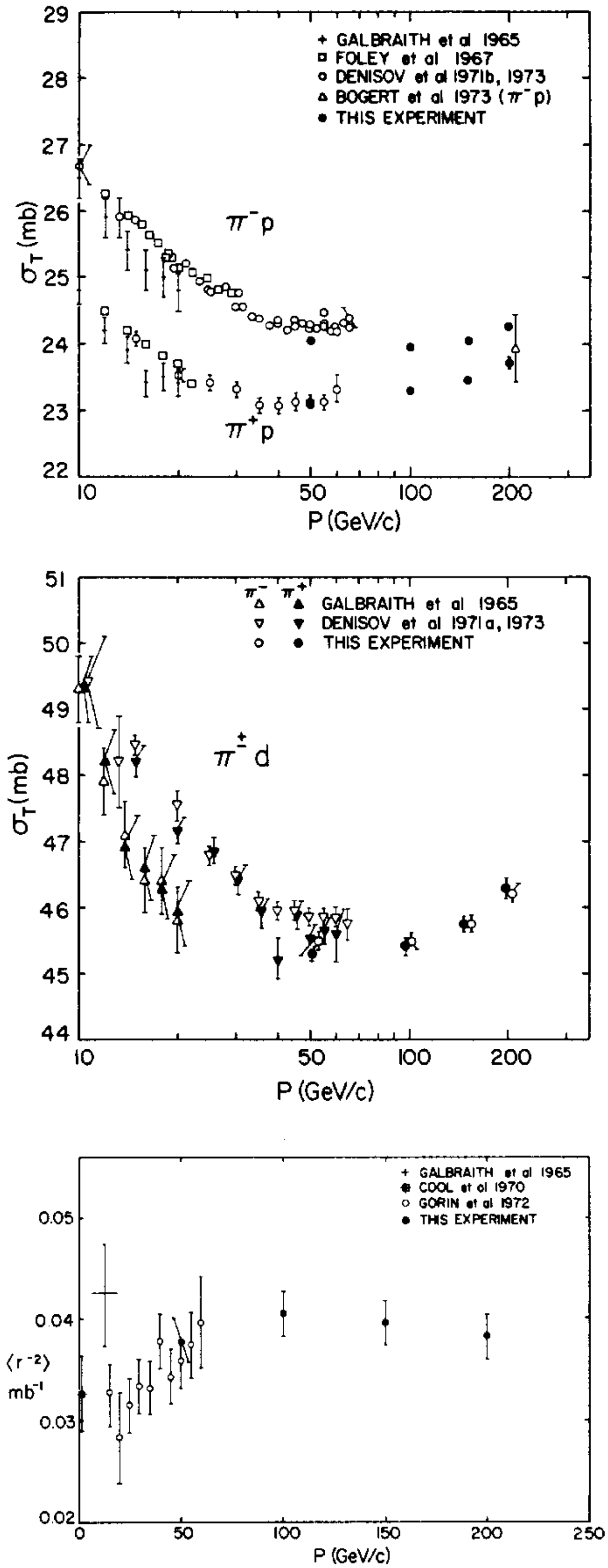
a) $K^{\pm}$ on protons;

b) $K^{\pm}$ on deuterons;

c) $K^{\pm}$ on neutrons.

Momentum dependent errors only are shown. Previous data are from References 2-7.

Figure 3: Results of this experiment, together with previous data, for total cross section differences $\sigma_{\pi^- p} - \sigma_{\pi^+ p}$, $\sigma_{K^- p} - \sigma_{K^+ p}$, $\sigma_{K^- d} - \sigma_{K^+ d}$ and $\sigma_{K^- n} - \sigma_{K^+ n}$. References as for Fig. 2.



GALBRAITH et al 1965
FOLEY et al 1967
DENISOV et al 1971b, 1973
BOGERT et al 1973 ($\pi^- p$)
THIS EXPERIMENT
$\pi^- p$
$\pi^+ p$
σ_T (mb)
P (GeV/c)
π^- π^+
GALBRAITH et al 1965
DENISOV et al 1971a, 1973
THIS EXPERIMENT
$\pi^\pm d$
σ_T (mb)
P (GeV/c)
GALBRAITH et al 1965
COOL et al 1970
GORIN et al 1972
THIS EXPERIMENT
$\langle r^{-2} \rangle$
mb^{-1}
P (GeV/c)

Fig. 1

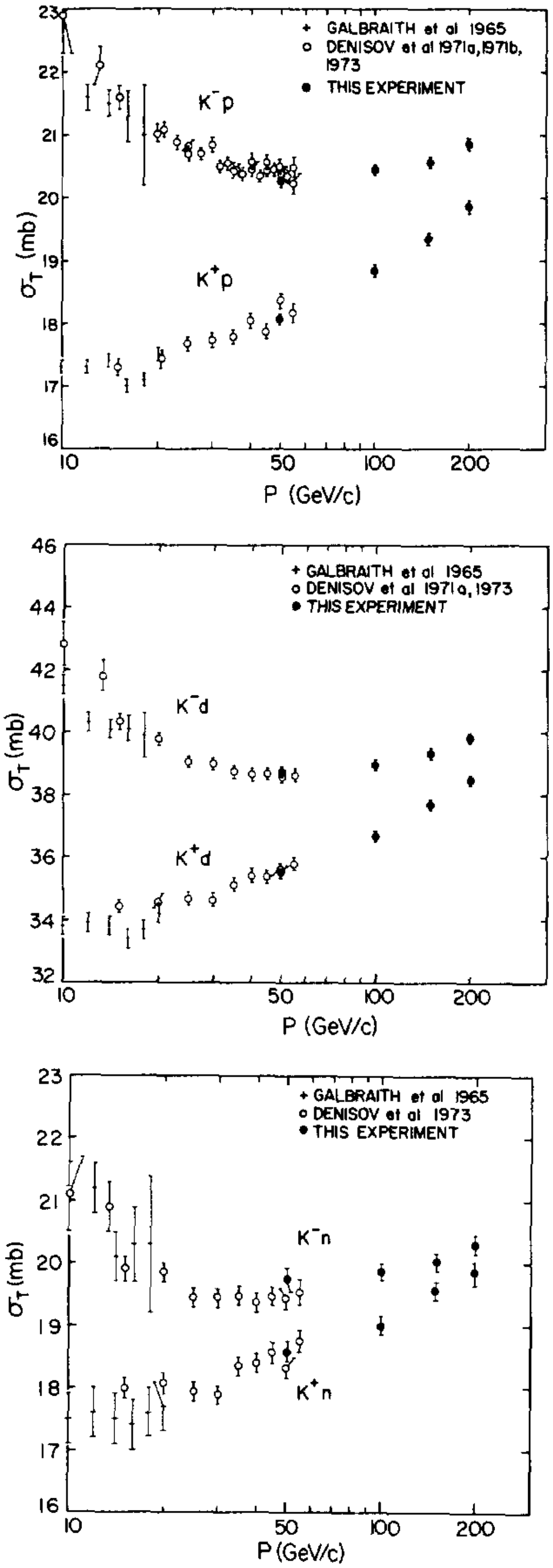
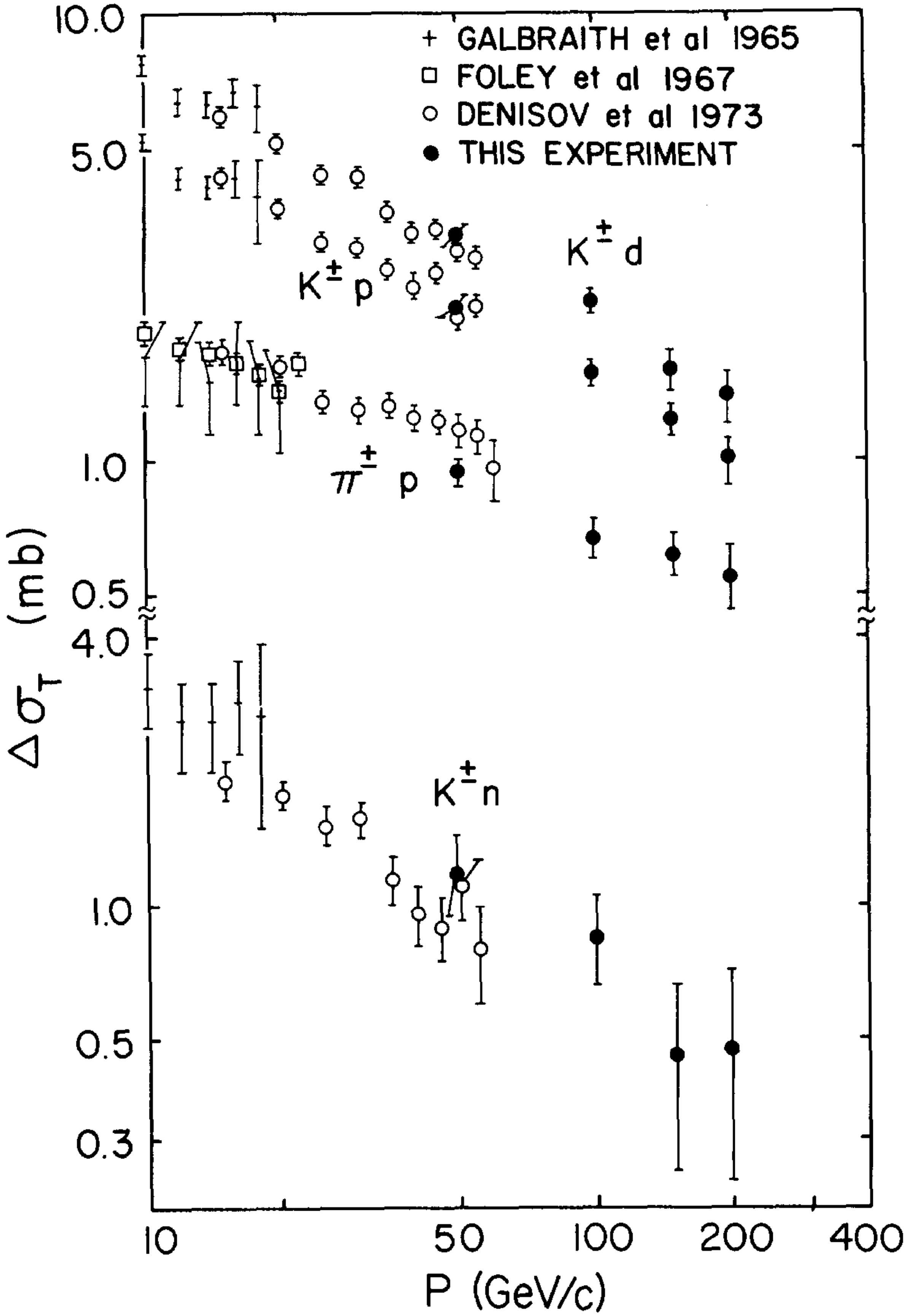

GALBRAITH et al 1965
DENISOV et al 1971a, 1971b, 1973
THIS EXPERIMENT
K⁻p
K⁺p
σ_T (mb)
P (GeV/c)
GALBRAITH et al 1965
DENISOV et al 1971a, 1973
THIS EXPERIMENT
K⁻d
K⁺d
σ_T (mb)
P (GeV/c)
GALBRAITH et al 1965
DENISOV et al 1973
THIS EXPERIMENT
K⁻n
K⁺n
σ_T (mb)
P (GeV/c)

Fig. 2



+ GALBRAITH et al 1965
□ FOLEY et al 1967
○ DENISOV et al 1973
● THIS EXPERIMENT
$K^{\pm}p$
$K^{\pm}d$
$\pi^{\pm}p$
$K^{\pm}n$
10.0
5.0
1.0
0.5
4.0
1.0
0.5
0.3
$\Delta\sigma_T$ (mb)
10
50
100
200
400
P (GeV/c)

Fig. 3